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ABSTRACT

This study investigated the effects of mental ability level on prcblem solving behavior of individuals and dyads. The problem (riddle of the death of the Wooly Mammoth) is open ended, data rich and presented by computer. Significant interactions between grouping (individual and dyad) and ability (above average, above + below average and below average) were found for fluency measures of Number of Data Requests and Number of Data Matches and for the efficiency measure of Total time engaged in the problem. Significant main effects of ability level for data usage measures (Proportions of Positive and Neutral Data received and Average Time examining Neutral Data) was found. (Author)

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A Comparison of Individual and Dyadic Problem Solving Performance as a Function of Mental Ability on a Computer Based Task

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A paper presented at the meeting of the American Educational Research Association, New York City, April 1977.

This study examined the effects of level of mental ability upon the problem solving processes of individuals and dyads engaged in an open-ended, data-rich problem. Mental ability was defined as the subject's general ability with symbolic operations.

Rationale

Maier (1971), has recommended the development of innovative instructional systems which will enable students to have greater responsibility for their academic progress. Maier's suggestion inspires an investigation of student problem solving behavior. Problem solving facility enables the student to formulate solutions to problems within as well as outside of the classroom. The provisional nature of instruction necessitates the development of a large degree of student self-sufficiency (Bruner, 1964); therefore instruction should increasingly stimulate the active participation of the learner. Maier's recommendation for greater opportunities for student responsibility in new instructional systems has the potential for easing the student's transition from the classroom to the "outside world."

Glaser (1976) has suggested that studies of problem solving processes may reveal instructional strategies useful for teaching "learning how to learn" techniques. Resnick and Glaser (in press) suggest that certain problem solving processes may resemble the processes involved in learning without the complete instructions of the teacher. Research in problem solving processes has the potential for instructional design which incorporates psychological theory and educational practice (Glaser, 1976).

Innovative instructional systems may be devised with plans for

alternative student-teacher or student-student interactions. Goldshmid (1971) describes the learning cell which is a dyadic unit of two students who mutually teach and learn. Little research has emerged on this type of peer-assisted relationship in problem solving activities.

Reid, Palmer, Whitlock and Jones (1973) suggest an examination of the benefits of student interaction on problem solving tasks with specific attention to the individual characteristics which are functioning in such interactions. Reid et al. suggest that research be undertaken to determine the differential effects of one versus two students working on a problem. They also suggest an investigation of individual characteristics which combine in the dyadic unit to determine which type of dyad functions most effectively in a problem solving situation. The present study investigated a segment of the issues raised by Reid et al. by focusing on the individual characteristic of mental ability level and its influences upon performance of dyadic and individual problem solving.

Literature Review

Maier, in a summary of studies conducted prior to 1963, found group problem solving to be superior, inferior, as well as equal to individual problem solving. These conflicting findings apparently are the result of comparison of a variety group compositions, problem types and analysis procedures. Perhaps a strict generalization about the quality of group verses individual problem solving performance cannot be made.

Lorge and Solomon (1955) devised two mathematical models which suggest that the superiority of the group is a function of the increased probability that one of its members can solve the problem, which in turn is a matter

of ability. These models, like Steiner's Complementary Task Model (1966), suggest that group members pool complementary information enabling the group to exceed the performance of its best individual. If however, the key to successful problem solving is this factor of ability it would appear that a group of low ability members would pool divergent information inhibiting an individual who may be successful. The models imply an interaction between grouping (group vs. individual) and ability level.

Goldman (1965) tested the proposals of the Complementary Model by a study in which the performance of pairs of various combinations of ability were compared with that of individuals working independently. Goldman categorized subjects as High, Middle or Low ability on the basis of their scores on the Wonderlic Intelligence Test (Wonderlic, 1938). The subjects took an equivalent form of the test at a later date in paired and independent conditions. The pairs recorded mutually agreed upon answers so that each pair obtained one score. Goldman found that the pair-groups improved significantly more than the individuals and that the pairing effect was greatest for those subjects who were low scoring on the first administration of the test. The subjects working with partners at their same level did not improve over working with subjects below their level. Much of Goldman's results support the proposals of the Complementary Model. However, his finding that the subjects working with partners of the same ability level did not improve over working with partners below their level is contradictory of the model. The model predicts that a pair of high scoring subjects would exhibit greater improvement than a pair of high and low scoring subjects. It is proposed that the low scoring subject would contribute little unique information and that the pair of high scoring

individuals would contribute a substantial amount of unshared resources. Laughlin and Johnson (1966) suggest that Goldman's partial confirmation of the proposals of the Complementary Model is a result of a speeded test improperly administered as a power test. A test used in this fashion resulted in a clustering of scores at the higher end of the scale. This negatively skewed distribution was a result of the limited amount of unshared information possible in High ability pairs. Another consideration is that Goldman's problem solving task was a second administration of the measure he used to determine ability level.

Laughlin and Johnson conducted a partial replication of Goldman's study using the Terman Concept Mastery Test (Terman, 1960) to eliminate the ceiling effect. They found, like Goldman, that across all ability levels the pairs improved more than the individuals. Like Goldman, Laughlin and Johnson used their measure of ability as their problem solving task.

Lorge and Solomon did not specify the type of ability responsible for the difference observed between group and individual performance. A reasonable possibility is mental ability, defined as skill with symbolic operations. The research exploring the relationship between mental ability, considered to be a component of intelligence, and problem solving has not yielded conclusive results. Raaheim and Kaufmann (1974) have suggested that factors aside from ability such as range of task difficulty, knowledge of implements, presence of certain tools, experience, or motivation can confound the relationship between problem solving and ability. In a study which attempted to control for a number of these extraneous variables, Raaheim and Kaufmann found a significant positive relationship between mental ability and success in problem solving tasks. Rhoades (1977) using

the mammoth simulation found that mental ability was a significant discriminating variable in relation to selected problem solving criteria when used with other predictors in a multiple discriminant analysis study.

The research conducted by Goldman (1965) and Laughlin and Johnson (1966) suggest that differential pairing of individuals by general ability level affects problem solving performance. Both of these studies measured effectiveness of the problem solution in terms of reaching a criterion. It appears that there is a relationship between ability levels and subjects working alone or in pairs as shown by examinations of single solution problems. The difference must also be observable in the processes which the subjects use to reach solution.

Fluency

Specific processes of problem solving have been investigated without differential grouping of subjects. One process criterion measure used specifically in studies of creative problem solving has been fluency or the number of responses generated for a given problem. Renzulli, Owen and Callahan (1974) suggest that increased fluency is one of the goals of group problem solving. Torrance (1970), with specific attention to individual and dyadic problem solving, found increased fluency in the dyadic condition. Torrance compared open-ended problem solving performance of individuals and dyads five years old and twenty-one years old.

Efficiency

Another process criterion measure is the efficiency of the solution. This measure may be particularly valuable in light of Torrance's research. Dyadic problem solving may stimulate more solutions, but the time expended generating these solutions may be more effectively used in pursuit of other

educational activities. The efficiency of solutions may be measured in terms of time to reach solution. Husband (1940) suggests that problem solving in dyads must take less than one half the time utilized by individuals during problem solving to be efficient. Taylor and Faust (1952) tested Husband's proposal and found individual performance in a twenty questions task to be superior to that of 2 and 4 member groups in terms of man-minutes to reach solution.

Traditionally, efficiency of problem solving has been defined as total time needed to reach criterion. This measure is inadequate for open-ended problems which do not have one standard solution. Efficiency may also be measured in terms of the time expended in the process of searching for relevant data from which to make problem conclusions.

Data Usage

Shaw (1932), Thorndike (1938) and Tate and Stanier (1964) have suggested that the use of positive and negative information be measured. In a study by Rhoades and Szabo (1976) time spent examining positive and negative data was significantly related (through multiple discriminant function analysis) to intelligence and hypothesis formation skills. Shulman and Elstein (1975) noted the apparent disregard of negative data in complex decision-making involving medical personnel.

Bloom and Broder (1950) and Simon (1975) have argued that the payoff in problem solving studies will come from understanding the processes employed by problem solvers, not whether they have achieved a 'correct' solution. Perhaps the process criteria identified in the problem solving literature can reveal the cause for the difference observed in the single solution studies of dyads and individuals organized by ability level. The open-ended problem provides the opportunity to measure the fluency, efficiency and data usage

which are processes hinted at in the single solution problem studies.

On the basis of the Lorge and Solomon Model, Steiner's Complementary Task Model and the problem solving process criteria suggested above, it was expected that interactions exist between grouping (individuals vs. dyads) and mental ability level on criteria measures of fluency, efficiency and data usage.

Method

Design

The design of this study was a 2 X 3 analysis of variance with two levels of grouping (individuals and dyads) and three levels of mental ability (above average, above + below average, and below average) as determined by scores on the Otis Quick Scoring Mental Ability Test (Otis, 1954).

Subjects

The subject pool was composed of 121 undergraduate student volunteers enrolled in Educational Psychology courses. Ninety students were selected to be in the study proper as determined by their scores on the Otis Quick Scoring Mental Ability Test (Otis, 1954).

Variables

The independent variables in this study included: 1) grouping (individual vs. dyadic cooperative) during solution attempt and, 2) mental ability as described above.

The following problem solving criteria were used as dependent variables in this study: (a) fluency measures of: number of hypotheses, number of data requests and number of data matches; (b) efficiency measures of: total time participating in the problem solving session and the average time spent devising each hypothesis; and (c) data usage measures of: proportions of positive,

negative and neutral data received and average times spent examining positive, negative and neutral data. A particular piece of data was determined to be positive if it supported a hypothesis posed by the subject. Negative data contradicted a posed hypothesis. Neutral data served as background material or was completely unrelated to a hypothesis.

Apparatus

The Otis Quick Scoring Mental Ability Test, Form Gamma-AM was used was used to determine a mental ability level for each subject.

The experimental task was to solve the riddle of the frozen wooly mammoth. This is a complex problem which requires the subject to hypothesize, request information and form new hypotheses concerning the possible causes for the death and burial of the wooly mammoths found preserved in the Arctic tundra. The problem of the wooly mammoth was devised by Riban and Szabo (1968). This problem, known as MAMMO, was programmed for the IBM 1500 system in Coursewriter II by Szabo and Rhoades (1977). The heuristic version (Mode II) was used. The IBM 1500 computer system with terminals composed of a cathode ray tube, an image projector and a keyboard was used as a data source, a feedback mechanism and as a monitoring system which tracked the subject's problem solving activity (see Appendix A).

Procedure

The Otis Quick Scoring Mental Ability Test, Form Gamma-AM was administered to the subject pool. On the basis of their scores the subjects were classified as above average, average or below average. The above average and below average subjects were randomly assigned to one of six conditions in which they were to pursue the experimental task: 1) above average (AA) individuals, 2) one half above average and one half below average (A+B) individuals, 3) below average (BA) individuals, 4) AA dyads, 5) A+B dyads and

and 6) BA dyads. Ten individuals or dyads were assigned to each condition (see Figure 1). Those subjects who scored within two standard errors of measurement of the mean were not included in the study.

During the problem session the subjects were confronted with the problem to be solved in printed form. The confrontation emphasizes the bizarre circumstances surrounding one of the mammoth finds. The subjects were given an on-line introduction to the IBM 1500 system and were asked to read the confrontatic The subjects were requested to develop hypotheses for the problem and request data from the simulation program to verify or dispute the hypothesis posed. During the solution attempt, the simulation provided various content-free heuristics (based upon sets or chains of data presented) and evaluated the conclusions posed (Szabo & Rhoades, 1977). After two hours the subjects ended the problem session at their will by forming final conclusions.

Results

Each variable of the three categories of dependent variables (fluency, efficiency and data usage) was analyzed by a 2 X 3 Between Subjects Analysis of Variance.

Fluency Criteria

Significant disordinal interactions between grouping and ability level were observed for number of data requests [F (2,54)=4.29, $p < .05$] and number of data matches [F(2,54)=3.55, $p < .05$]. Follow-up tests, using the Tukey WSD technique revealed AA dyads requested significantly more data than AA individuals. The mean scores for this interaction are displayed in Figure 2. Follow-up tests for the number of data matches indicated BA dyads received significantly less data matches than BA individuals and A+B dyads. The means

Mental Ability Level	C_1 Individual	C_2 Dyad
Above Average Otis $\geq$ 118	Above n = 10	Above + Above n = 10 pairs
Above Average $\bar{x} \geq$ 118 Below Average $\bar{x} \leq$ 112	Above n = 5 Below n = 5	Above + Below n = 10 pairs
Below Average Otis $\leq$ 112	Below n = 10	Below + Below n = 10 pairs

Figure 1. 2 x 3 Design of Present Study

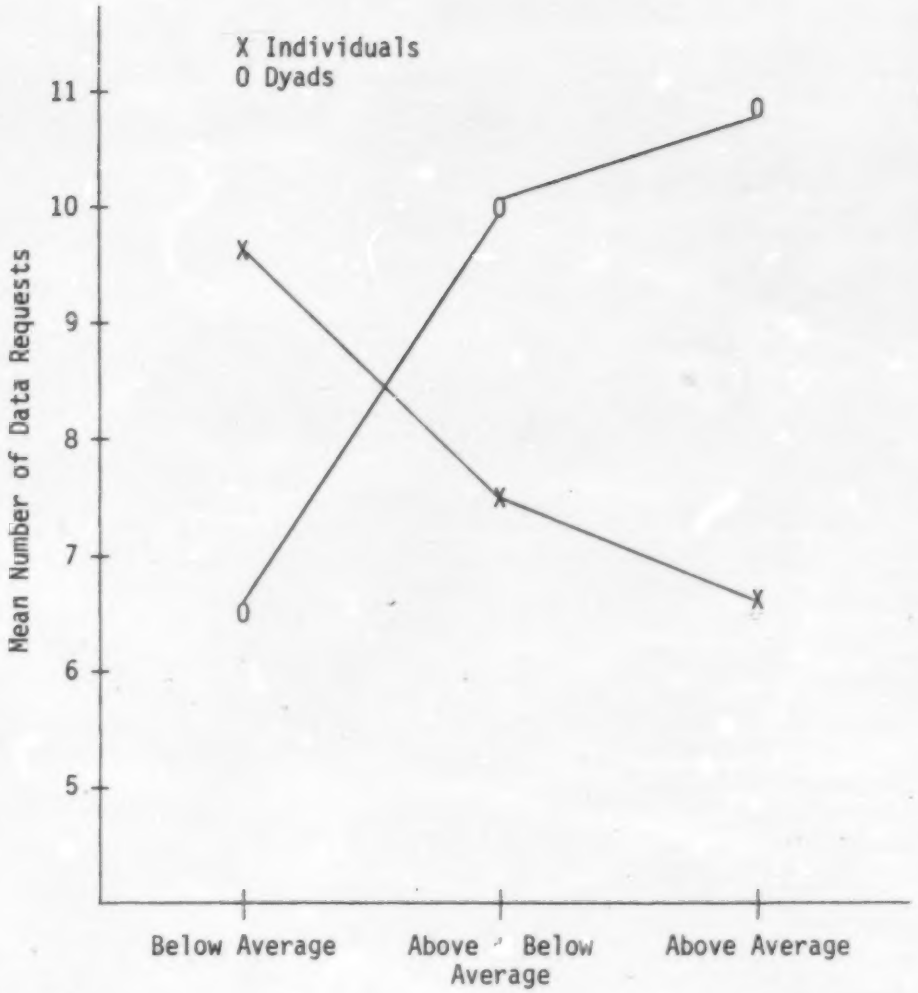

Figure 2. Grouping by Mental Ability Level Disordinal Interaction for Mean Number of Data Requests

of this interaction are displayed in Figure 3. The results of the analysis of variance with the fluency criterion variable of number of hypotheses indicated nonsignificant effects.

Efficiency Criteria

The results of the analyses of the efficiency criteria variables indicated a significant disordinal interaction for the total time participating in the problem solving session [$F(2,54)=4.98$, $p<.05$]. Follow-up tests indicated AA individuals spent significantly less time engaged in the problem than AA dyads. BA individuals spent significantly more time than BA dyads. The means of this interaction are displayed in Figure 4. The results of the analysis of the average time devising each hypothesis yielded nonsignificant results.

Data Usage Criteria

On the analyses of the data usage variables nonsignificant results were observed for the proportion of negative data presented and average times spent examining positive and negative data. Significant main effects of mental ability were found for proportions of positive data presented [$F(2,54)=18.30$, $p<.05$] and neutral data presented [$F(2,54)=13.19$, $p<.05$]. Follow-up tests of these two variables indicated that AA subjects received significantly more positive and less neutral data than A+B subjects, who in turn received more positive and less neutral data than BA subjects. The analysis of the average time spent examining neutral data yielded significant main effects of grouping [$F(2,54)=4.64$, $p<.05$] and ability level [$F(2,54)=7.56$, $p<.05$]. Dyads considered neutral data for longer periods of time than individuals. AA subjects and A+B subjects spent significantly less time on neutral data than BA subjects.

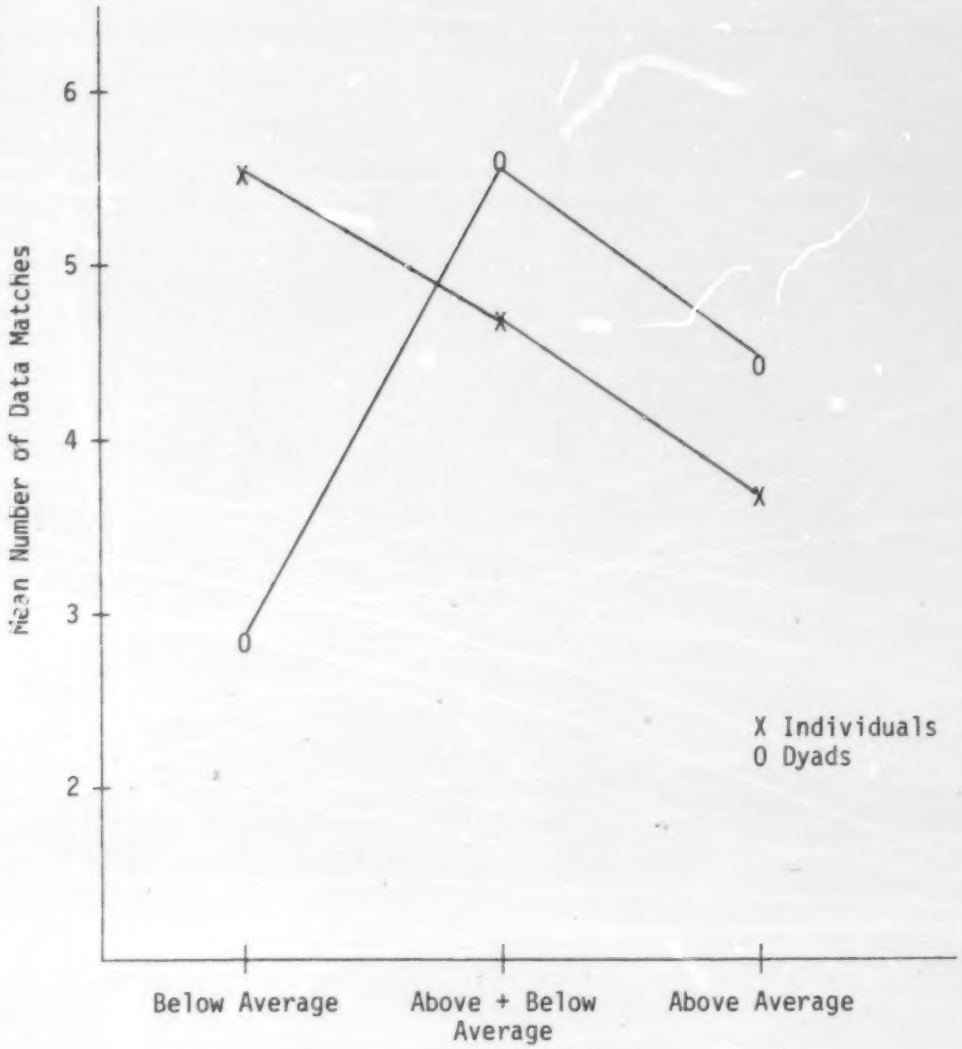

Figure 3. Grouping by Mental Ability Level Disordinal Interaction for Mean Number of Data Matches

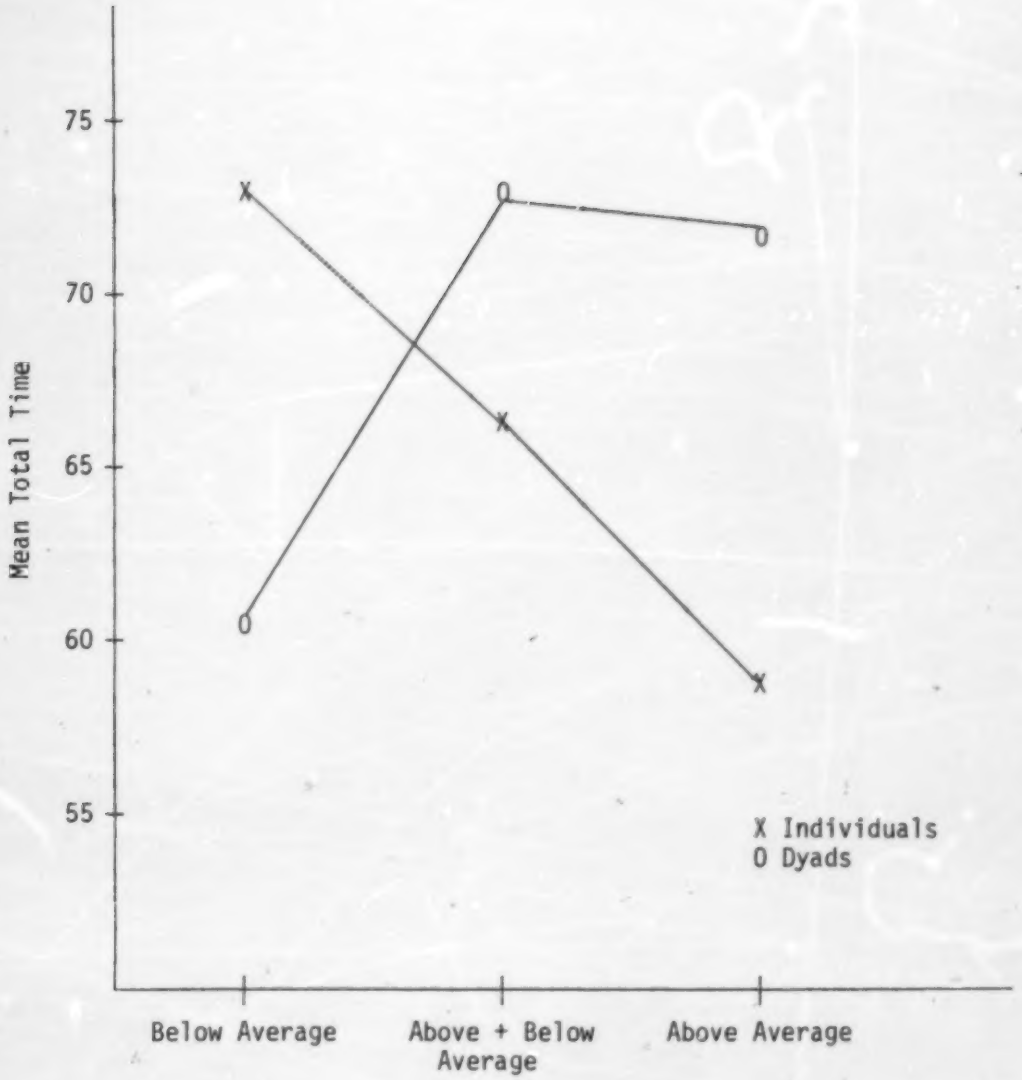

Figure 4. Grouping by Mental Ability Level Disordinal Interaction for Mean Total Time

Discussion

The unique design of the MAMMO simulation facilitated the examination of problem solving processes predicted from the work of researchers who used single solution tasks in their studies (Shaw, 1932; Thorndike, 1938; Husband, 1940; Harootunian & Stanier, 1960; Tate & Stanier (1964). Therefore with few studies resembling the present problem task, this study was exploratory in method as well as theory.

The present study posed that when the ability level of the group is above average the performance will be superior to that of individuals and that when ability level is below average the performance will be inferior to that of individuals (Lorge & Solomon, 1955, Steiner, 1966). This expected interaction of grouping and mental ability level was confirmed by certain measures of fluency and efficiency. Individuals searched for, received and consumed information differently than dyads as a function of their menetal ability levels. Generally, the interactions suggest that the BA dyads requested and received less data and participated for less time than BA individuals. The AA dyads requested and received more data than AA individuals. The performance of the A+B dyads generally resembled that of AA dyads.

The measures of the number of hypotheses and average time devising each hypothesis yielded nonsignificant results. Perhaps the differences between hypotheses of AA and BA individuals and dyads do exist using the criterion of hypothesis quality in addition to or in place of quantity. Rhoades (1977) used the mammoth task in a multiple discriminant analysis study and found that the quality of hypotheses in conjunction with other variables had significant positive discriminant coefficients for classifying good and poor problem solvers.

For measures of data usage the ability level of the subject appears to be the determinant for the type of data received and the length of time it was processed. Perhaps higher ability subjects are more capable of requesting information which specifically relates to their hypotheses. The analysis of the average time examining positive data yielded nonsignificant results. Perhaps the subjects skimmed over data they already knew. The analysis of the average time examining neutral data yielded results consistent with the research of Levine (1969); that is, BA subjects spent significantly more time examining data which negated their hypotheses. Perhaps the neutral data were studied for background information which the BA subjects did not possess prior to the problem session.

The mixed dyad of A+B ability should be examined more carefully. In the present study the performance of this type of dyad closely resembled that of the AA dyad rather than that of the BA dyad. Recordings of the mixed dyads' interactions during the problem session may reveal that little work is accomplished by the BA member or a facilitative relationship exists between the dyad members. Research examining this relationship has the potential for revealing the rationale for developing peer-assisted study opportunities.

The results of the present study indicate significant differences between individuals and dyads, organized by mental ability level, in certain processes with theoretical relation to problem solving. Future investigations should devise guidelines for "good" problem solving techniques by using realistic open-ended tasks. These investigations would enable researchers to translate the results of process studies, such as the present, into instructional strategies.

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